

Calorimeter simulation: Gflash & PHA tuning



Charles Currat - LBNL



- The Gflash package: principles & interfacing
- Tuning procedure on data & results in PHA
- Conclusions

☞ Geant3-based offline detailed simulation ...

☞ top pairs @ 2 TeV
@ $10^{32} \text{ cm}^{-2} \text{ s}^{-1}$?!?

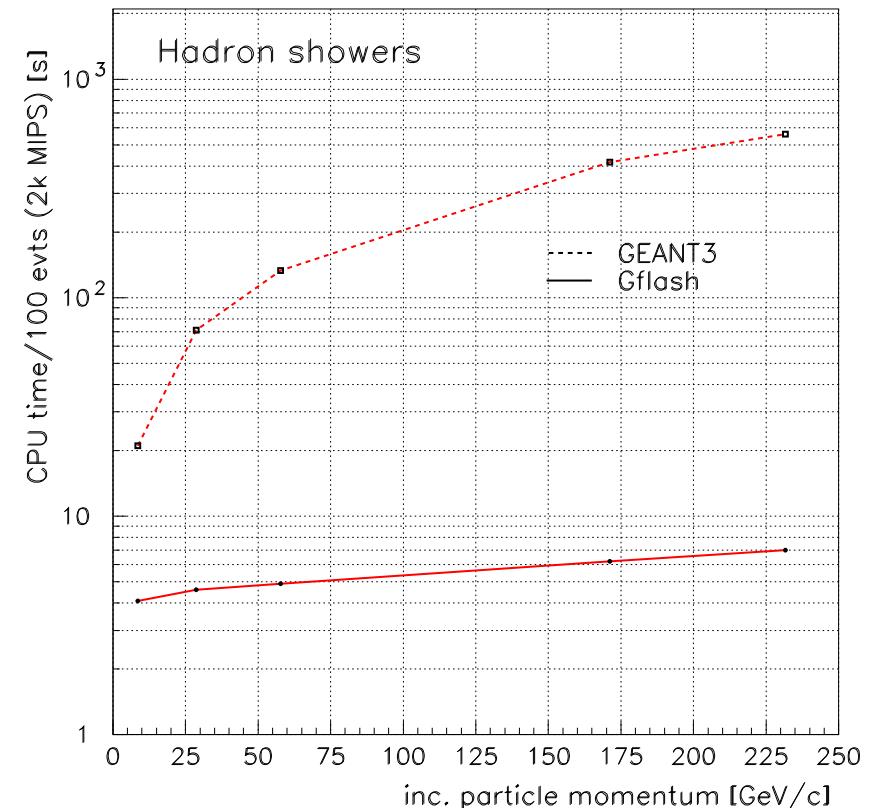
Find/use fast modelling of the showers instead in calorimeters simulation:

* **Gflash**: developed by H1 coll., 1990s

☞ EM+HAD showers, longitudinal
+ lateral profiles

CPU time increase with E

- * GEANT ... linear with E
- * Gflash as $\log(E)$



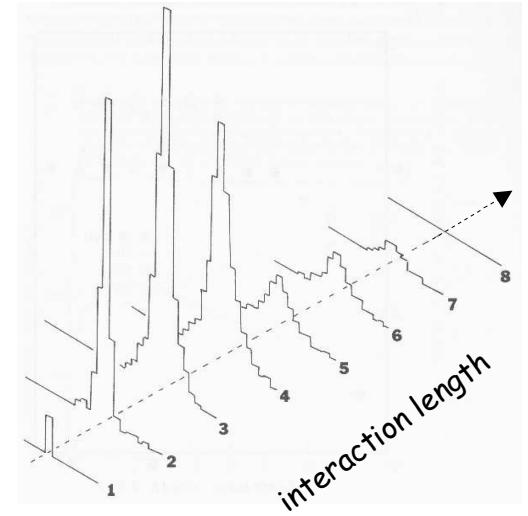
The Gflash package

- Single effective medium \Rightarrow fraction E_{vs} of deposited energy visible in active medium

$$dE_{vs}(\vec{r}) = E_{dp} \hat{m} \sum_k \frac{\hat{k}}{\hat{m}} c_k f_k(\vec{r}) dV$$

k=e,had

response to MIP response relative to MIP rel. fraction e versus had



☞ parameters with energy dependence of the form $a+b*\ln E$

- EM shower longitudinal profiles: gamma distribution $f(z) = \frac{x^{\alpha-1} e^{-x}}{\Gamma(\alpha)}$, $x = \beta z [X_0]$

• Lateral profile: Ansatz $f(r) = \frac{2r R_0^2}{(r^2 + R_0^2)^2}$... for both EM and HAD showers

☞ parameter $R_0 = R_0(E \text{ shower, depth})$

☞ no azimuthal dependence

- Correlation between α, β taken into account

$$\begin{pmatrix} \alpha_i \\ \beta_i \end{pmatrix} = \begin{pmatrix} \mu_\alpha \\ \mu_\beta \end{pmatrix} + C \cdot \begin{pmatrix} \text{rand 1} \\ \text{rand 2} \end{pmatrix} \quad \text{with} \quad C = \begin{pmatrix} \sigma_\alpha & 0 \\ 0 & \sigma_\beta \end{pmatrix} \cdot \begin{pmatrix} \rho_+ & \rho_- \\ \rho_+ & -\rho_- \end{pmatrix}$$

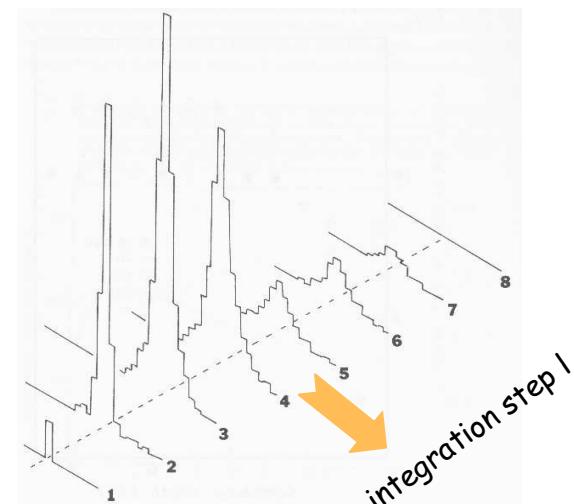
correlation: obtained from GEANT/data profiles (\sim indep. of E)

- Assuming energy resolution to be simulated is

$$\frac{\sigma_{dp}}{E_{dp}} = \frac{a}{\sqrt{E_{inc}}} \rightarrow E_{spot} = a^2 \cdot \frac{E_{dep}}{E_{inc}}$$

$$E_{dp} = \sum_l N_{spots(l)} \cdot E_{spot}$$

Poissonian \rightarrow sampling fluctuations



- Distribute E spots according to lateral profile

- Go from **deposited E** to **visible E**: sampling fractions $\hat{m}, \frac{\hat{k}}{\hat{m}}$

- 👉 Distinction between purely hadronic & π^0 components

HAD shower **longitudinal** profiles: 3 gamma distributions H, F, L

$$dE_{dp} = f_{dp} E_{inc} [c_h H(x) dx + c_f F(y) dy + c_l L(z) dz]$$

purely hadronic fraction π^0 fraction produced in 1st inelastic interaction π^0 fraction produced in further devel. of shower

👉 3 classes of events:
H / H+F / H+F+L
... with relative prob.
of occurrence
(deduced from GEANT)

3 mean values f_k, α, β and 3 fluctuations $\sigma_f, \sigma_\alpha, \sigma_\beta$ per **class** (component)

$$(f_k, \alpha_k, \beta_k, \sigma_{f_k}, \sigma_{\alpha_k}, \sigma_{\beta_k})_3 \rightarrow (x_i, \sigma_i)_{i=1,9}$$

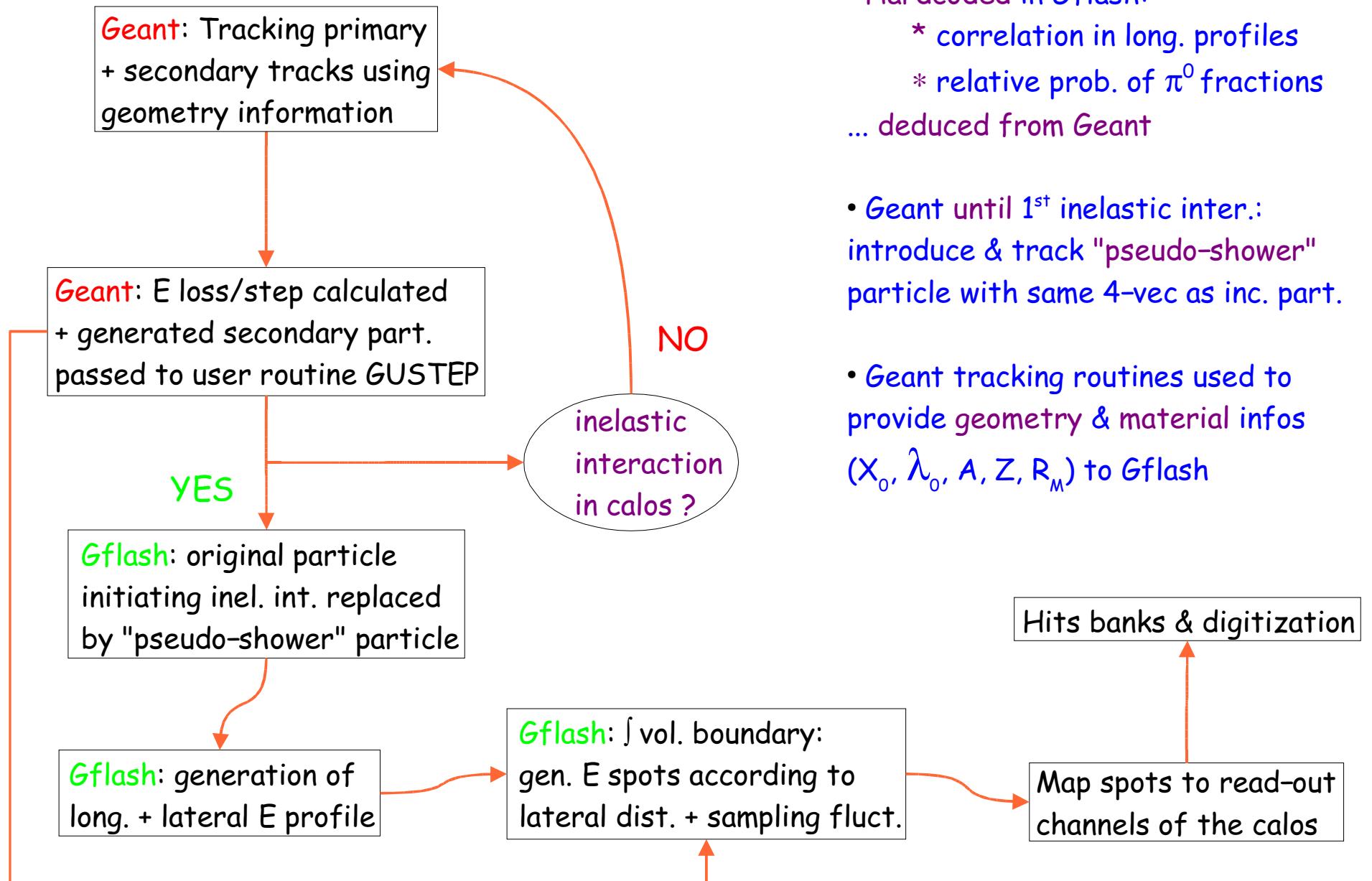
$$f_k = f_k(c_j)$$

$$\vec{x} = \vec{\mu} + C \vec{z}$$

$$\vec{\sigma} \rho \vec{\sigma}^T = CC^T$$

random numbers correlation matrix

👉 parameters with energy dependence of the form $a+b*\ln E$





Use calos test beam data: $e, \pi \dots$ ranging $8 < E < 250$ GeV



Tune Gflash

$$dE_{vs}(\vec{r}) = E_{dp} \hat{m} \sum_k \frac{\hat{k}}{\hat{m}} c_k f_k(\vec{r}) dV$$

1. Adjust MIP peak



2. Set E scale: response relative to MIP



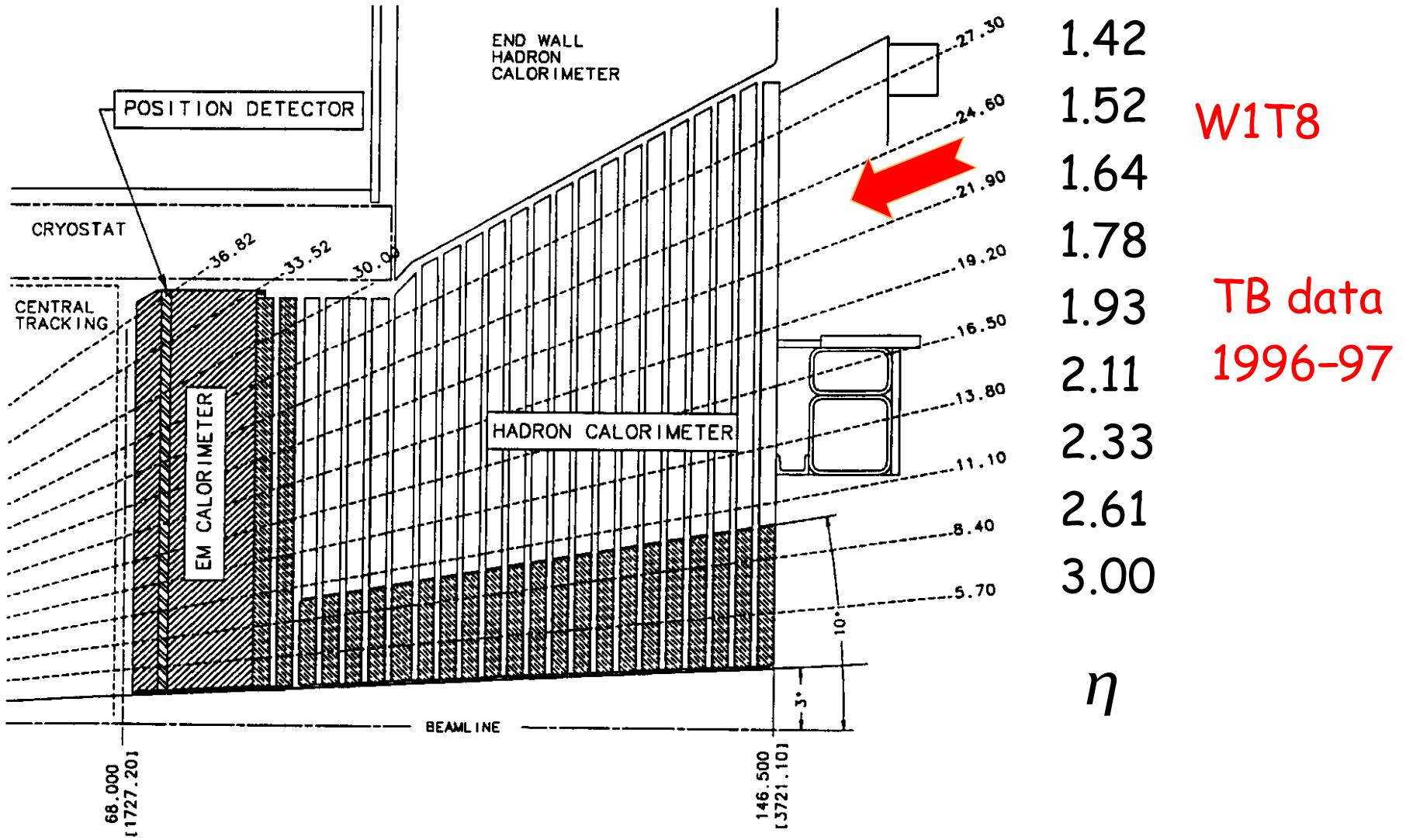
3. Adjust E dependence: $f_k = f_k(a + b \cdot \log E)$

☞ linearity, resolution

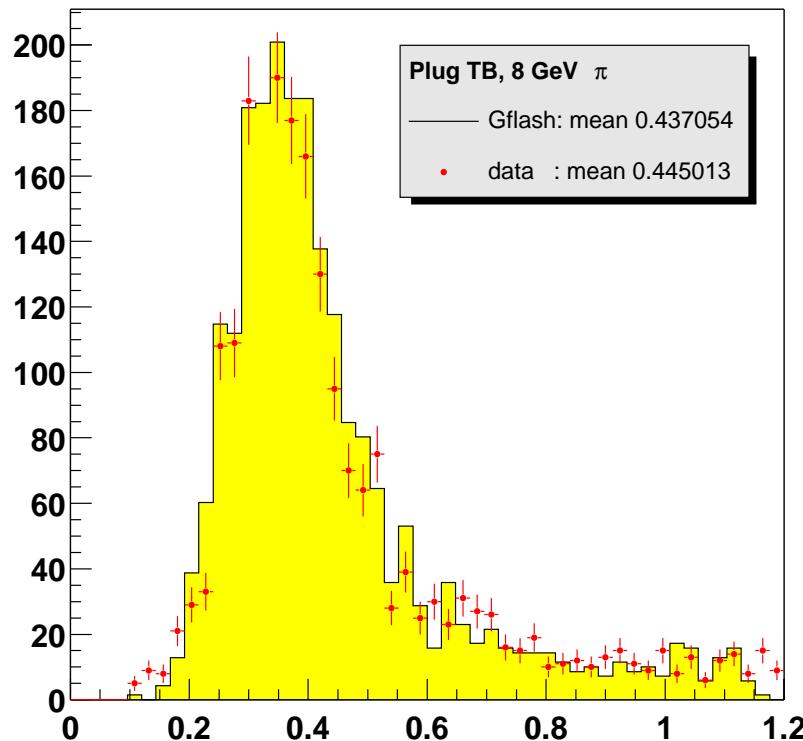
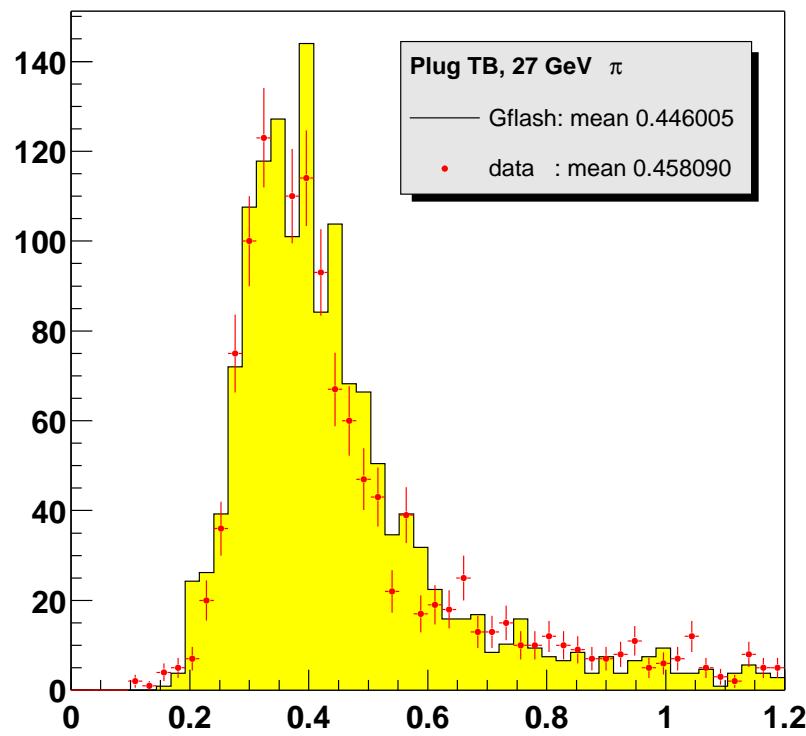
Results ...

Plug calorimeter

MC-workshop

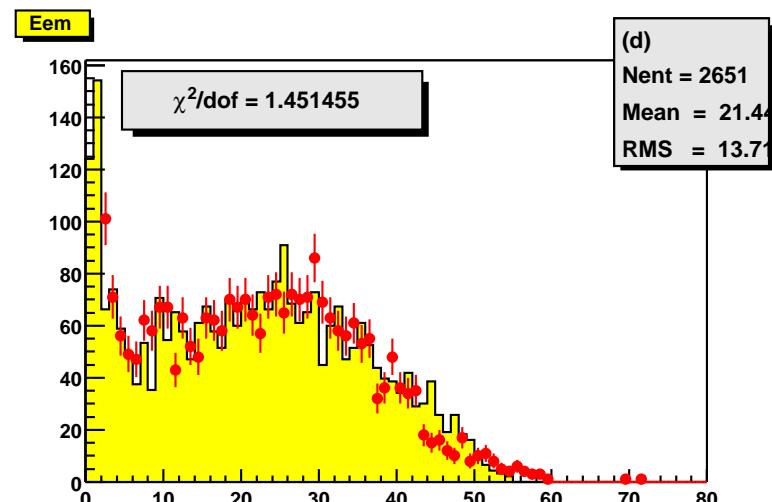
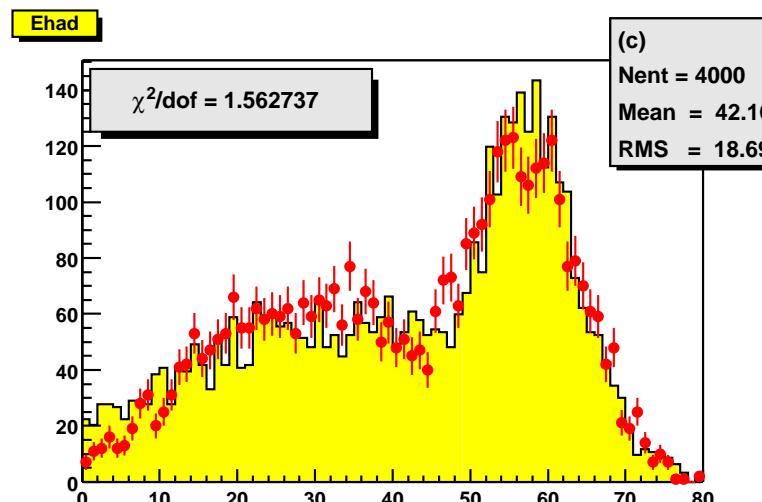
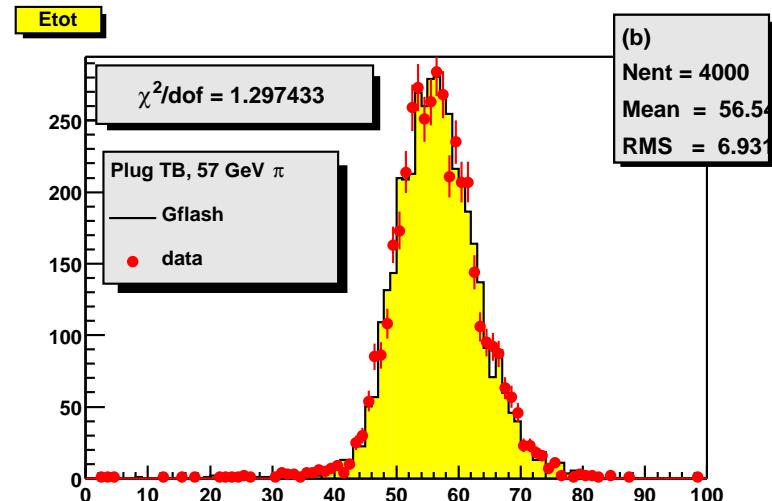
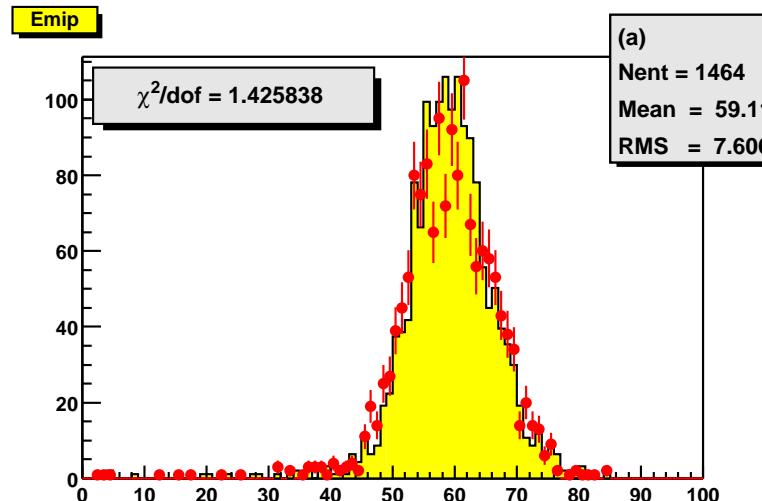


$$dE_{vs}(\vec{r}) = E_{dp} \hat{m} \sum_k \frac{\hat{k}}{\hat{m}} c_k f_k(\vec{r}) dV$$

MIP peak (PEM)

MIP peak (PEM)


$$dE_{vs}(\vec{r}) = E_{dp} \hat{m} \sum_k \left(\frac{\hat{k}}{\hat{m}} c_k f_k(\vec{r}) \right) dV$$

pions @ 57 GeV (fixed energy)



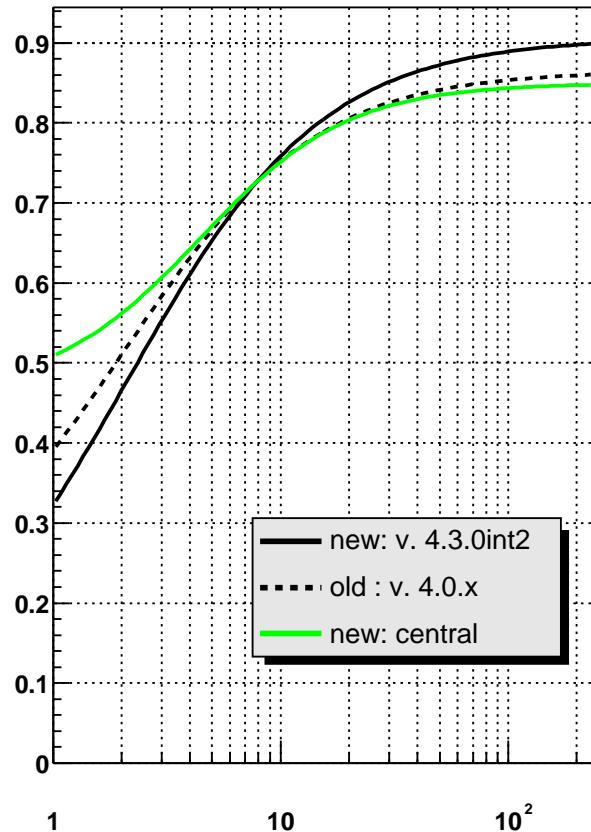
Adjusting the energy dependence

Hadronic showers: $f_k, \alpha, \beta = f_k(E), \alpha(E), \beta(E)$

☞ parameters with
energy dependence
of the form $a+b*\ln E$

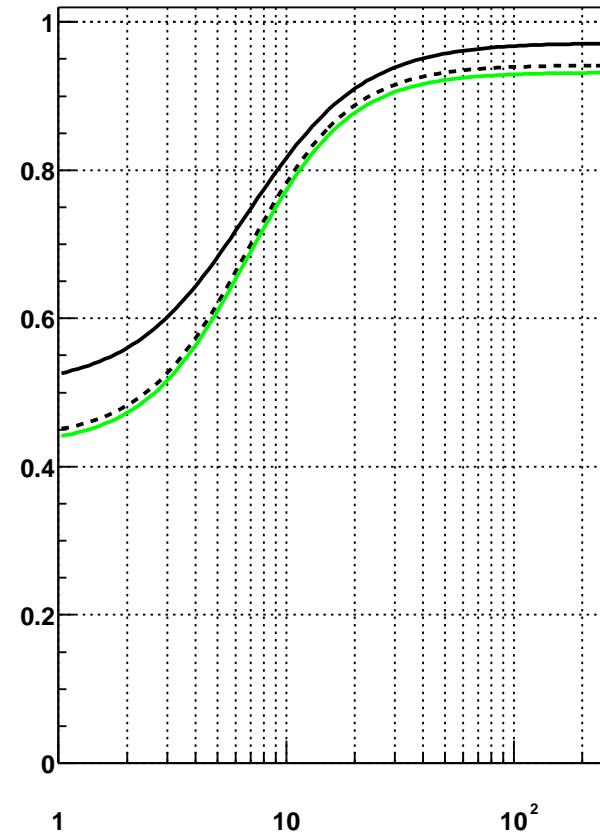
.. basically iterative ..

Fraction of deposited E (FDEP)



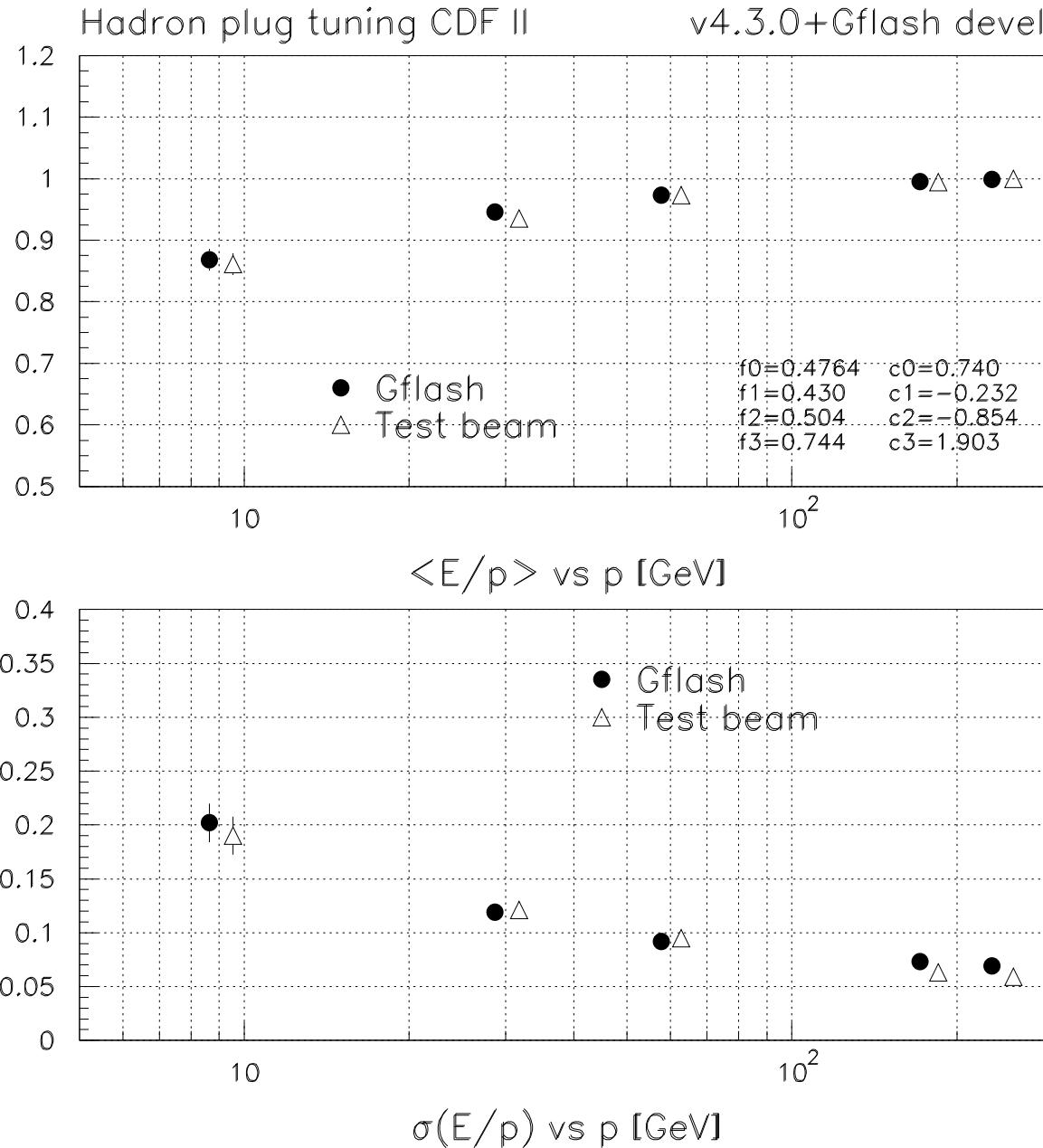
Pi0 fraction of deposited E (CPI0)

(1st interaction)

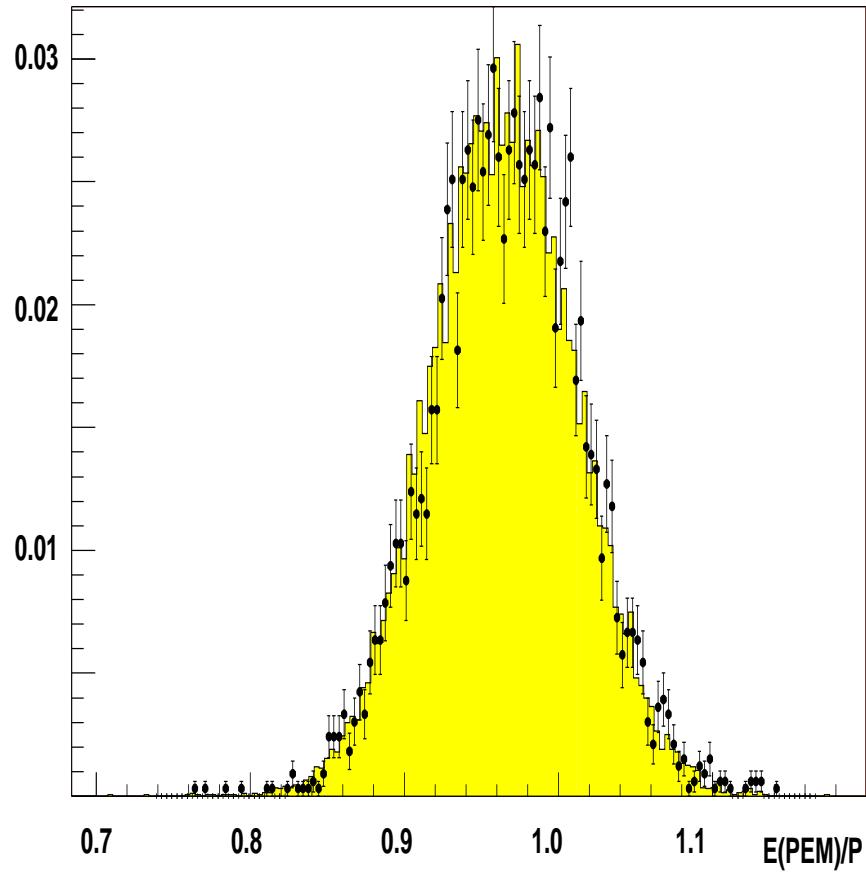


Energy dependence: linearity

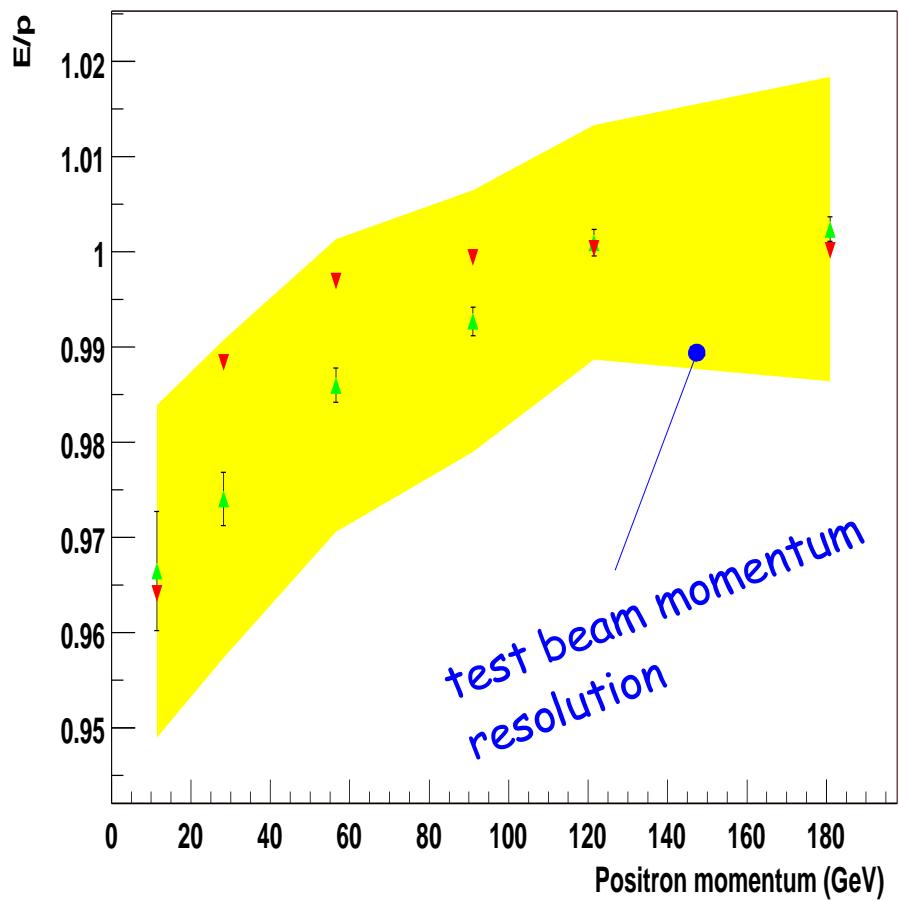
MC-workshop



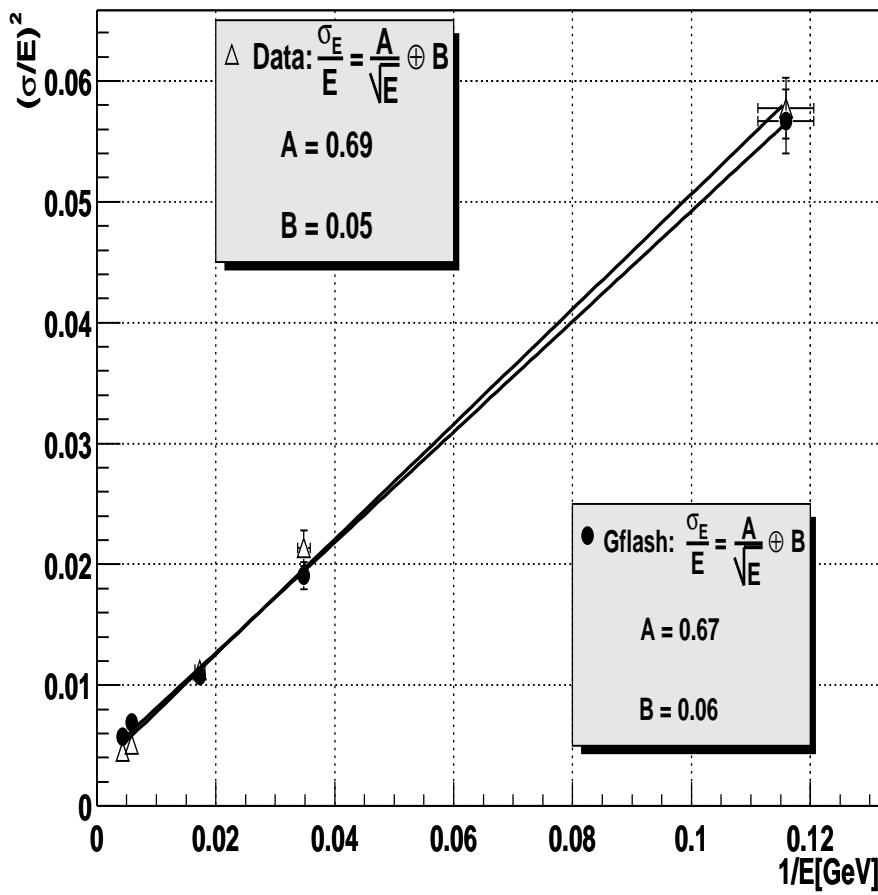
3x3 EM Energy over momentum, 11 GeV positrons



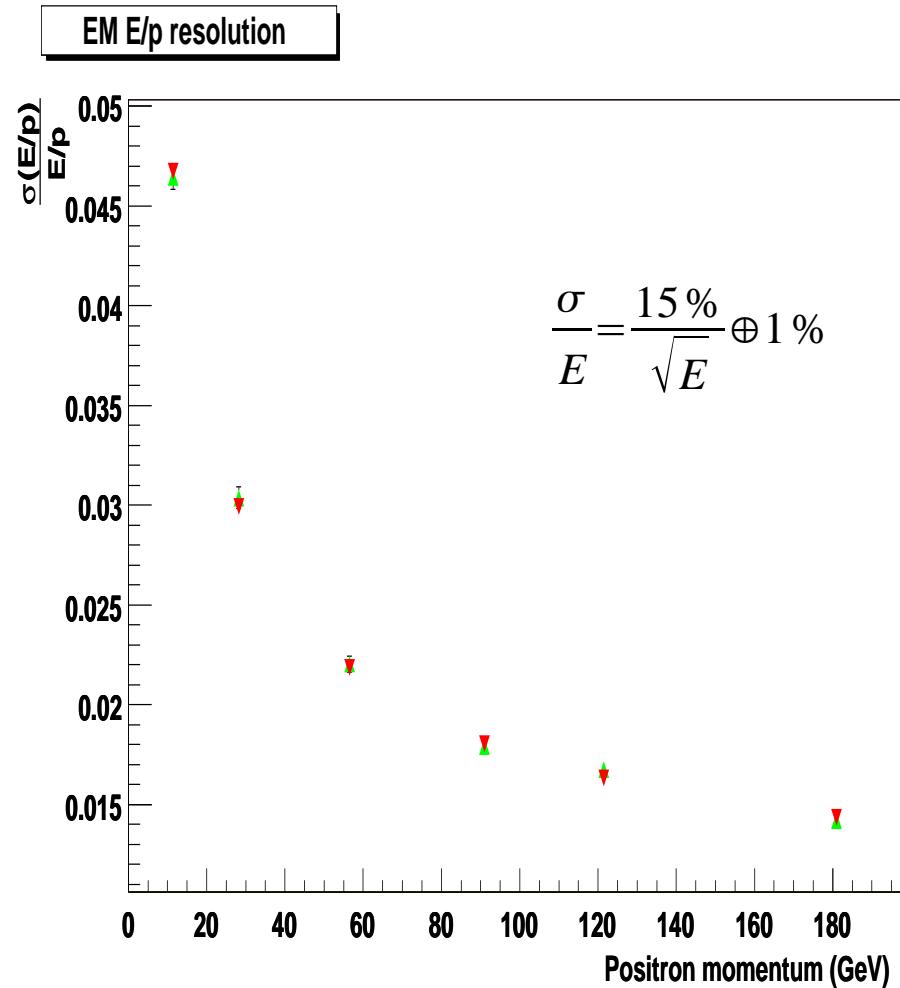
EM E/p linearity



pions



electrons





Outcomes & conclusions

MC-workshop

- Parameterized EM & HAD showers using Gflash ...

- over the full "4π" CDF calorimetry
 - over the range $8 < E < 250$ GeV

- Keeping robustness ...

- GEANT detailed geometry & material infos
 - no runaway of the parameterization: tuning by interpolation

- Gaining efficiency ...

- $\sim O(100)$ gain in CPU time for simulation

- Next steps: extensive tuning at low E / jets ... going on

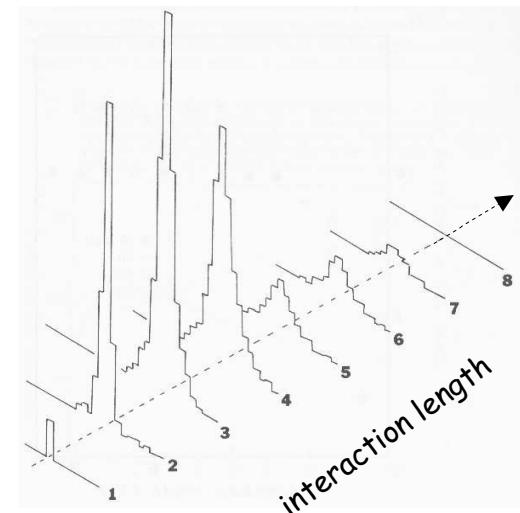
The Gflash package

- Spatial distribution of deposited energy E_{dp} for a shower

lateral

$$dE_{dp}(\vec{r}) = \frac{E_{dp}}{2\pi} \underbrace{f(z) dz}_{\text{lateral}} \overbrace{f(r) dr}^{\text{longitudinal}}$$

longitudinal



- Energy fraction of deposited energy E_{vs} visible in the **active** medium

$$dE_{vs}(\vec{r}) = E_{dp} \hat{m} \sum_k \frac{\hat{k}}{\hat{m}} c_k f_k(\vec{r}) dV$$

k=e,had
response to MIP
response relative to MIP
rel. fraction e versus had

parameters with
energy dependence
of the form $a+b*\ln E$

... next slide ...

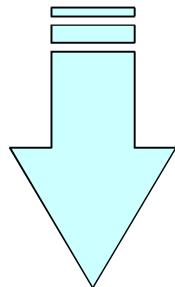
- EM shower **longitudinal profiles**: gamma distribution

$$f(t) = \frac{x^{\alpha-1} e^{-x}}{\Gamma(\alpha)}, \quad x = \beta t [X_0]$$

- **Lateral profile: Ansatz**

$$f(r) = \frac{2r R_0^2}{(r^2 + R_0^2)^2}$$

... for both EM and HAD showers



- note: no azimuthal dependence
- free parameter $R_0 = R_0(E \text{ shower, depth})$

~ calorimeter independent

- Parameterization of the fluctuations: log-normal R_0

$$\langle R_0 \rangle(E, z) = (R_1 + (R_2 - R_3 \log(E)) \cdot z)^n$$

$$\sigma_{R_0}^2(E, z) = (S_1 + (S_2 - S_3 \log(E)) \cdot z)^2 \cdot \langle R_0 \rangle^2$$

$n=2$... EM shower
 $n=1$... HAD shower

to get increasingly slower
shower spread with depth

